

# **Measurement of $Br(B^0 \rightarrow D_s^+ D^-)/Br(B^0 \rightarrow D^- \pi\pi\pi)$ at CDF**

Boris Iyutin  
Massachusetts Institute of Technology

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# Motivation

Use  $Br(B_s \rightarrow D_s^{(*)+} D_s^{(*)-})$  to measure  $\frac{\Delta\Gamma_s}{\Gamma_s}$

- $B_s \rightarrow D_s^+ D_s^-$  pure CP even eigenstate
- Fit CP even lifetime (provided enough statistics)
- Measure  $\frac{\Delta\Gamma_s}{\Gamma_s}$  from branching fraction

Complex analysis measuring several ratios of branching fractions.

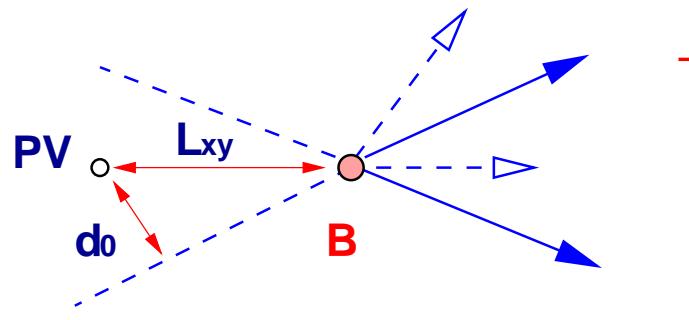
- Intermediate Step:  $\frac{Br(B_s \rightarrow D_s^+ D_s^-)}{Br(B^0 \rightarrow D_s^+ D_s^-)}$
- Test Case:  $\frac{Br(B^0 \rightarrow D_s^+ D_s^-)}{Br(B^0 \rightarrow D^- 3\pi)}$ , - Feature Presentation.

Combine three measurements for  $D_s^- \rightarrow \phi\pi^- (K^{*0}K^-, \pi^-\pi^+\pi^-)$

- Use similar 6-tracks  $B^0 \rightarrow D^- 3\pi$  and  $B_s \rightarrow D_s 3\pi$  to test tools and techniques
- $B_s \rightarrow D_s 3\pi$  - first observation, add statistics to  $B_s$ -mixing measurement

# Approach

## Data



- CDF Displaced Track Trigger data
- $243 pb^{-1}$  luminosity

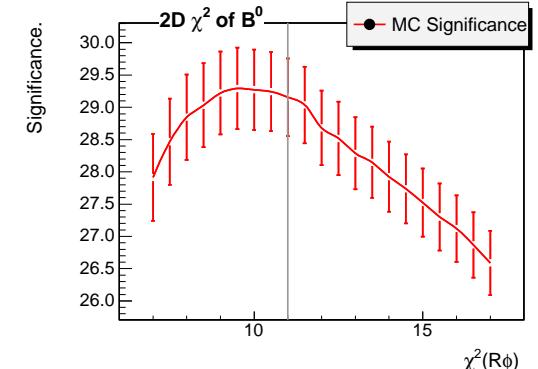
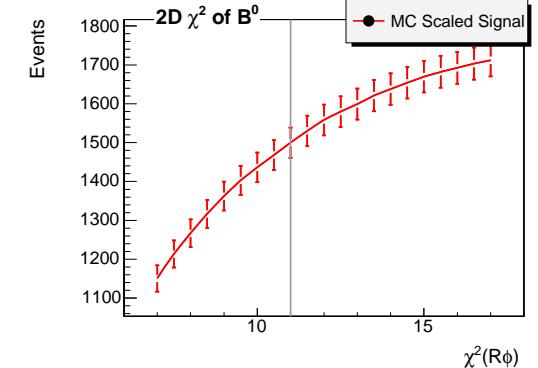
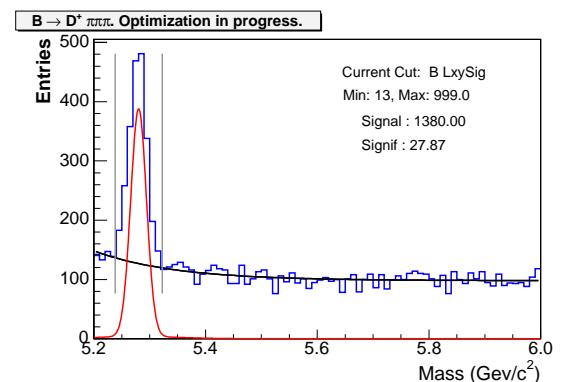
## Procedure

- Optimize selection cuts with signal MC and data BG
- Get selection efficiency ( $\epsilon$ ) from MC
- Get physics BG shape from MC for data mass fit
- Get yield ( $Y$ ) from data mass fit
- Calculate ratio

$$\frac{Br(B^0 \rightarrow D_s^+ D^- (\phi\pi))}{Br(B^0 \rightarrow D3\pi)} = \frac{Y(D_s D)}{Y(D3\pi)} \cdot \frac{\epsilon(D3\pi)}{\epsilon(D_s D)} \cdot \frac{Br(D_s \rightarrow \phi\pi, \phi \rightarrow KK)}$$

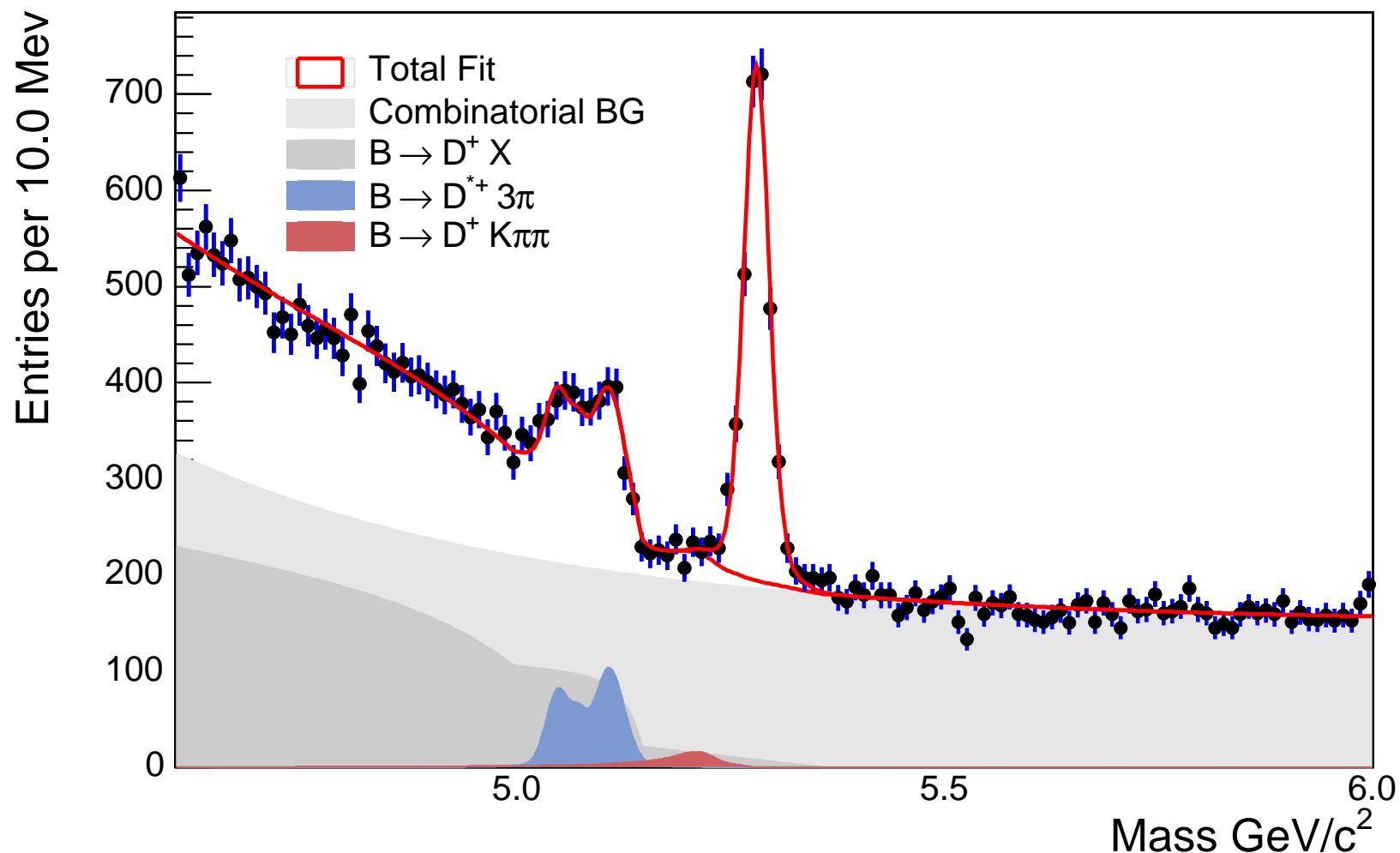
The biggest challenge, - make Data and MC agree

## Cut Optimization Snapshot



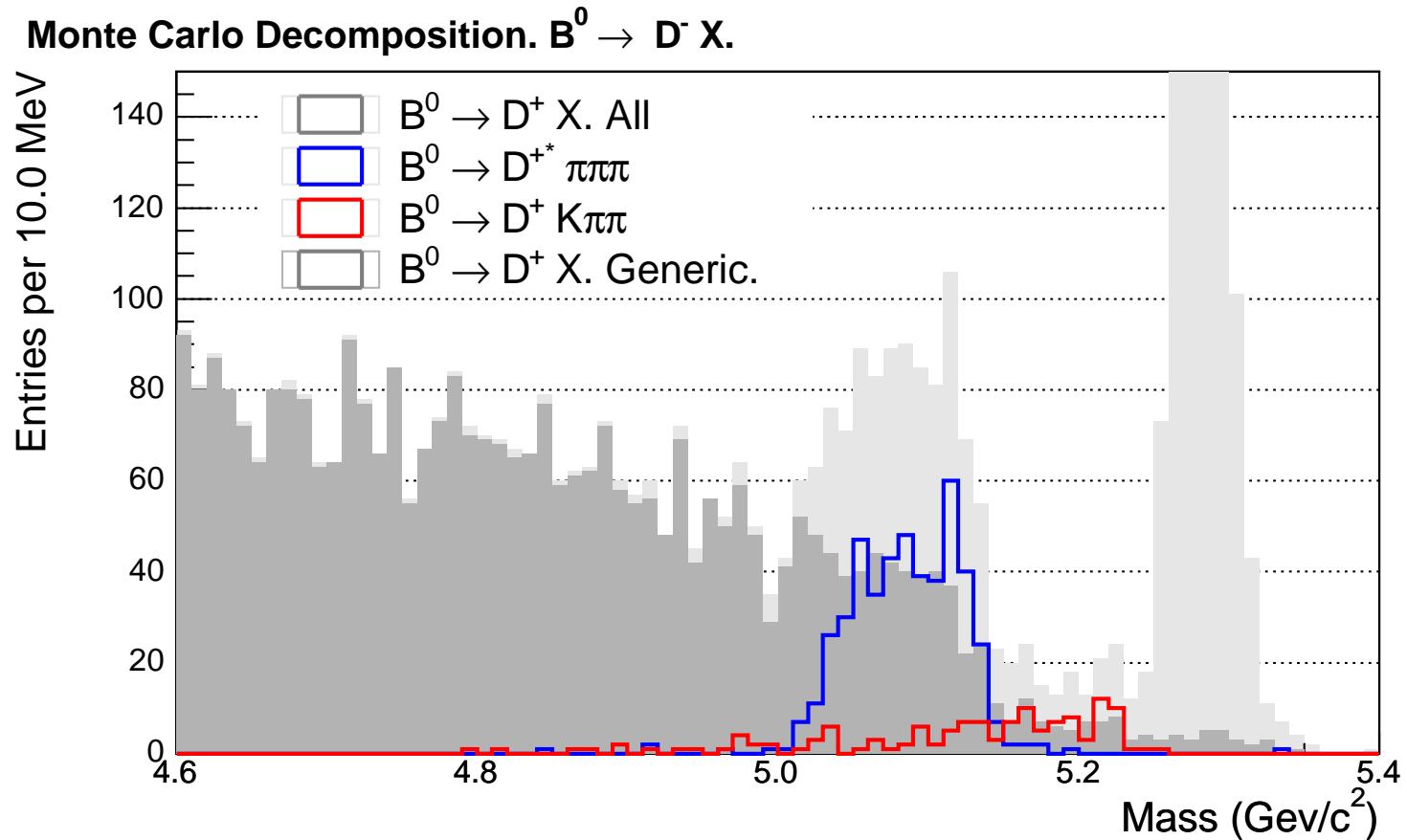
# Mass Fit $B^0 \rightarrow D^- 3\pi$

$B^0 \rightarrow D^+ \pi \pi \pi$ . CDF Preliminary.  $243 \text{ pb}^{-1}$ .



Use fixed shapes with floating relative normalization

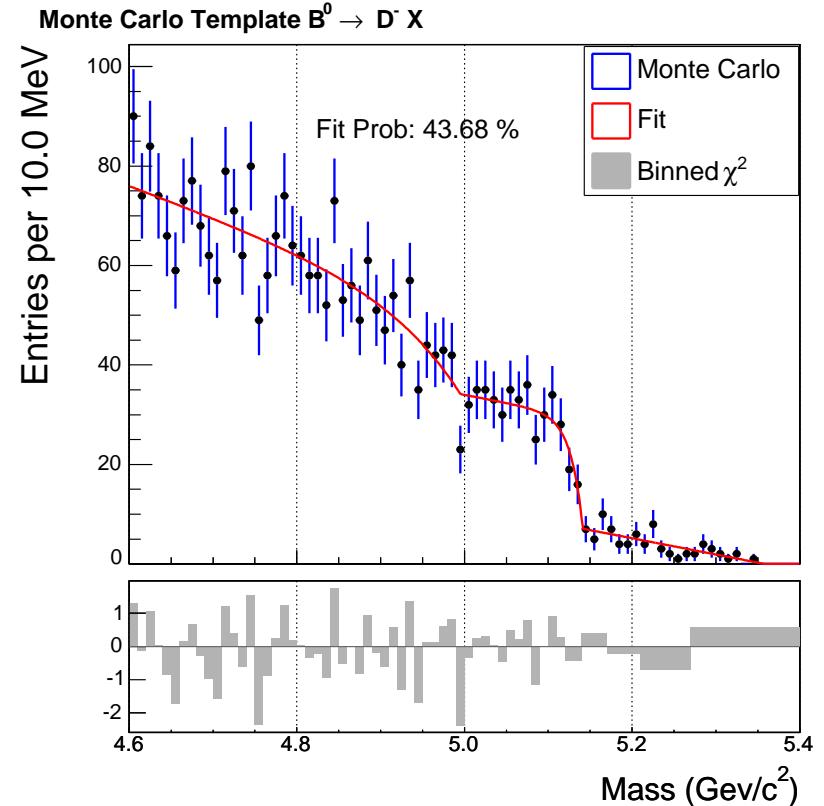
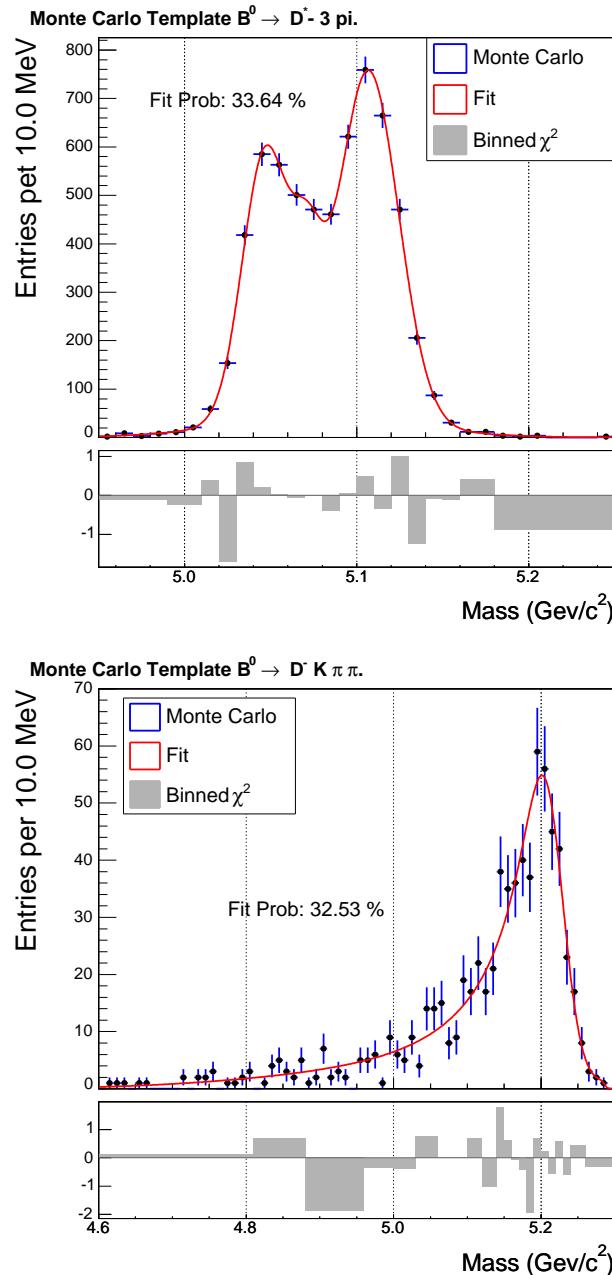
# Physics Background Monte Carlo $B^0 \rightarrow D^- 3\pi$



Decompose fitting template into components

- (*Blue Plot*) -  $B^0 \rightarrow D^{*-} \pi\pi\pi$ ,  $D^{*-} \rightarrow D^- \pi^0$ , - lost  $\pi^0$
- (*Red Plot*) - Cabibbo suppressed  $B^0 \rightarrow D^- K\pi\pi$ , - misreconstruct  $K$  as  $\pi$
- (Dark Gray Plot) - The rest  $B^0 \rightarrow D^- X$
- (Light Gray Plot) - All together and  $B^0 \rightarrow D^- \pi\pi\pi$  signal

# MC Shapes for $B^0 \rightarrow D^- 3\pi$ Mass Fit, More Statistics.

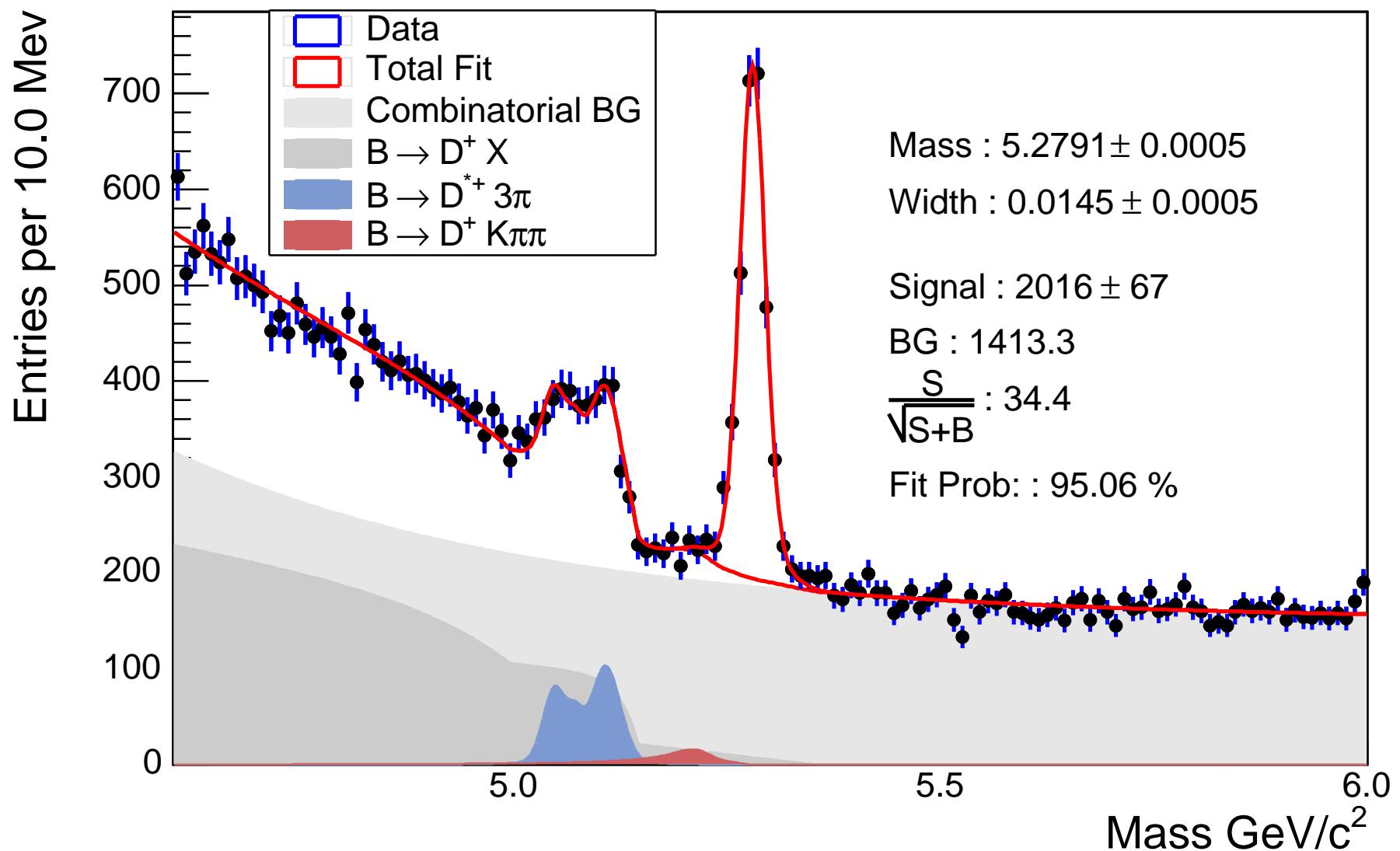


## Monte Carlo Shapes

- $B^0 \rightarrow D^{*-} 3\pi, D^{*-} \rightarrow D^- \pi^0$  (lost  $\pi^0$ )
- Cabibbo suppressed  $B^0 \rightarrow D^- K\pi\pi$
- The rest  $B^0 \rightarrow D^- X$  (generic)

# Mass Fit $B^0 \rightarrow D^- 3\pi$

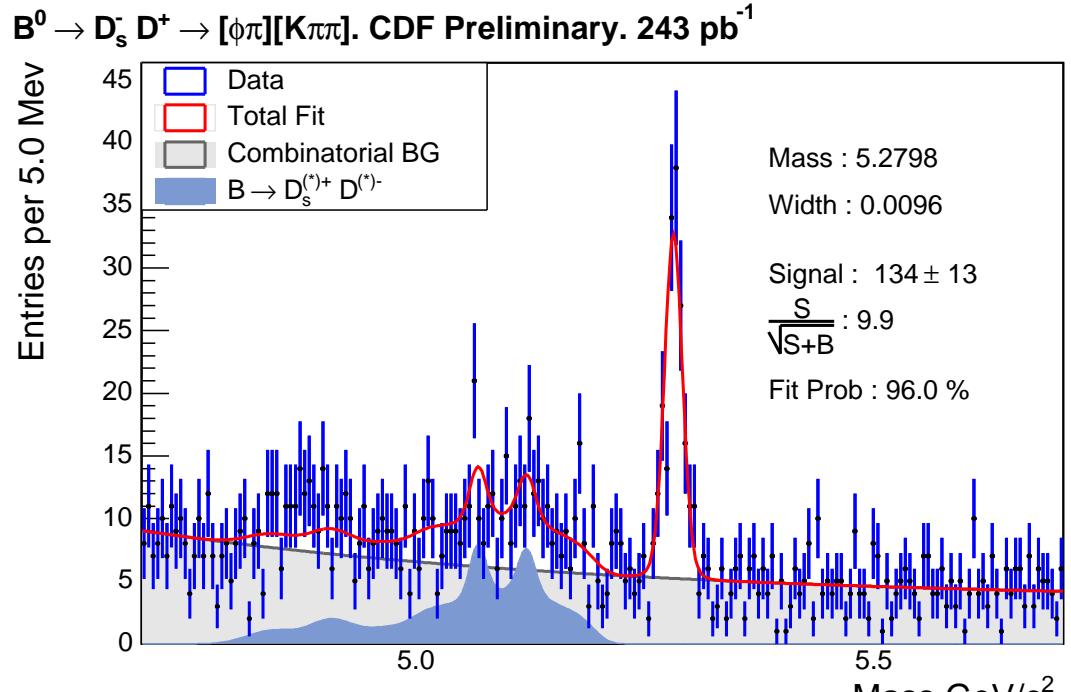
$B^0 \rightarrow D^+ \pi \pi \pi$ . CDF Preliminary.  $243 \text{ pb}^{-1}$ .



Switching to  $B^0 \rightarrow D_s^+ D^-$

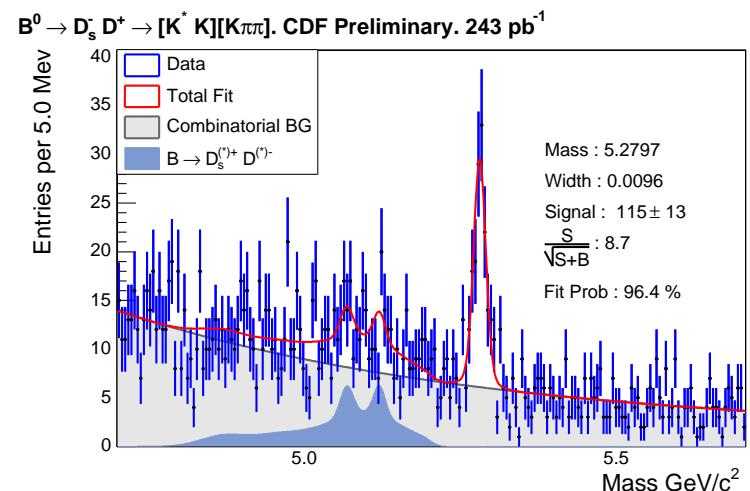
Use the same data and techniques

# $B^0 \rightarrow D_s^+ D^-$ Yields

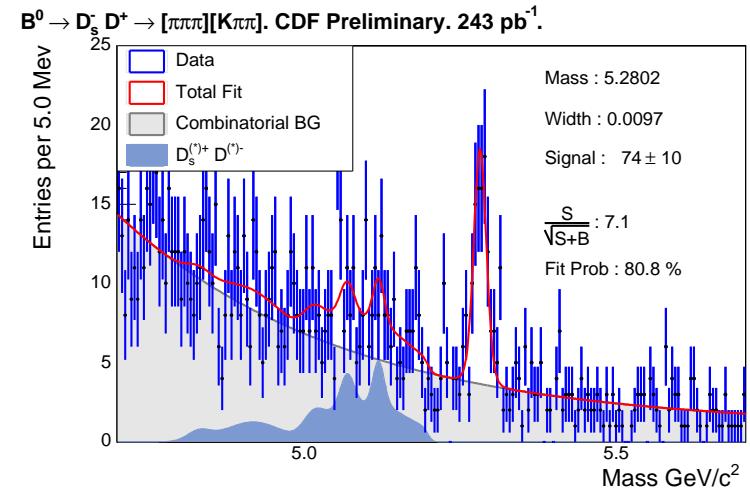


$D_s^+ D^- (\phi\pi)$  Signal:  $134 \pm 13$

- $D_s^{(*)+} D^{(*)-}$  combined together into blue shape
- Note  $D_s^{(*)+} D^{(*)-}$  and  $D_s^+ D^-$  separation
- $\phi$  and  $K^*$  resonances help to lower background.
- Can do the same with  $D_s^+ D_s^-$

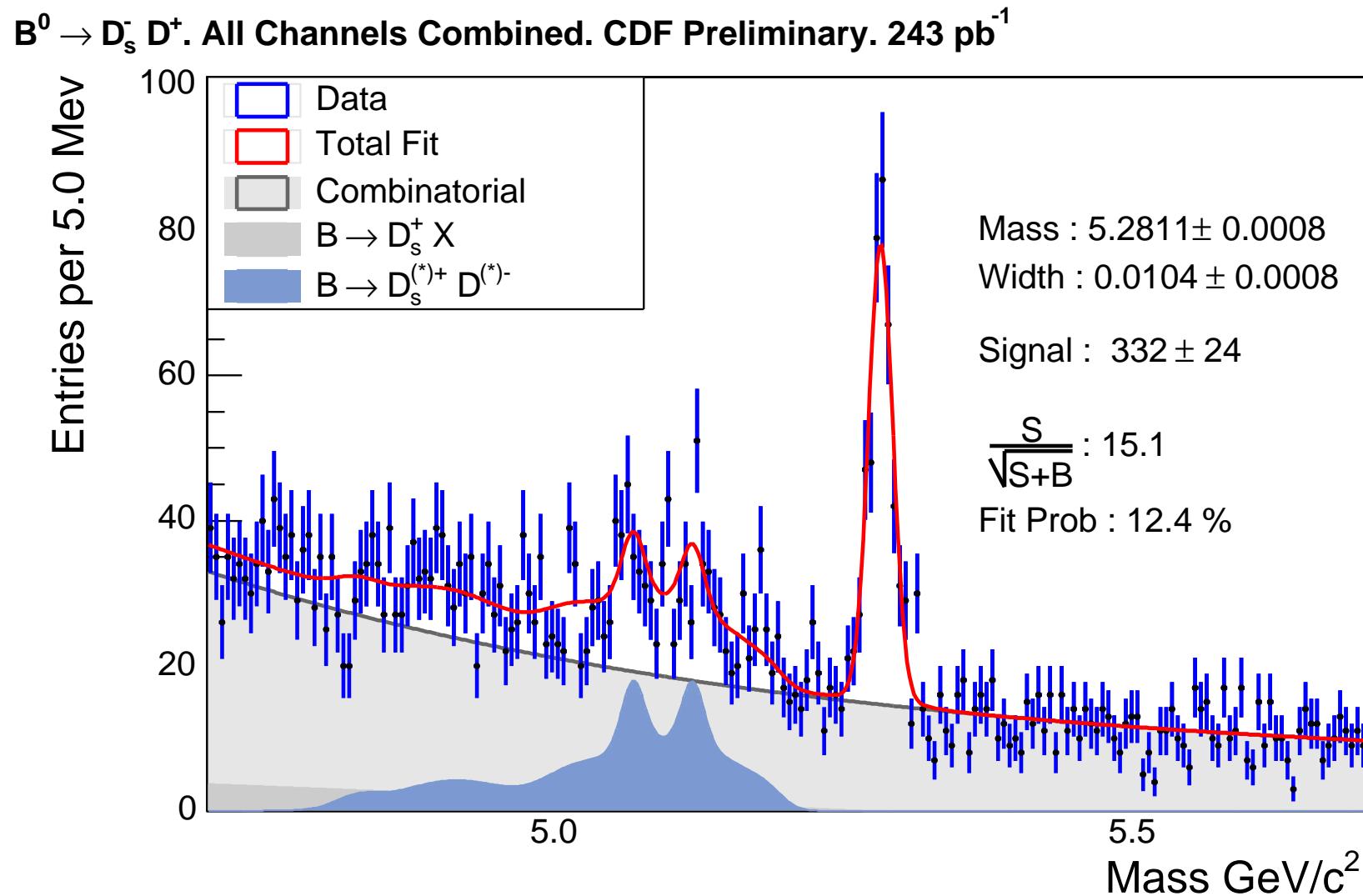


$D_s^+ D^- (K^* K)$  Signal:  $115 \pm 13$



$D_s^+ D^- (\pi\pi\pi)$  Signal:  $74 \pm 10$

# Combined Fit $B^0 \rightarrow D_s^+ D^-$



Fit is illustrational, - number is not used for final result

# Systematic Uncertainty Summary

Effect	Syst.[%]
Fit Model	$\pm 2.00\%$
$D_s^+ 3\pi, 3\pi$ Subresonances	$\pm 3.00\%$
Cut Values	$\pm 5.0\%$
Total Common Systematics	$\pm 6.2\%$
$D_s^+ D^- (D_s^+ \rightarrow 3\pi), 3\pi$ Subresonances	$\pm 3.00\%$
$D_s^+ D^- (D_s^+ \rightarrow 3\pi)$ Total Systematics	$\pm 6.9\%$

- Fit systematics address not perfect physics background model
- $3\pi$  uncertainty is due to poorly known  $3\pi$  subresonance structure for  $B^0 \rightarrow D^- 3\pi$ 
  - $B^0 \rightarrow D^- a_1, a_1 \rightarrow 3\pi$  - dominant
  - $B^0 \rightarrow D^- \rho\pi, \rho \rightarrow 2\pi$
  - $B^0 \rightarrow D^- 3\pi$
- Cut systematics due to different behavior of data and MC with respect to cuts
- $D_s \rightarrow 3\pi$  systematics is due to the poorly known  $D_s \rightarrow 3\pi$  composition

Most of the systematics due to the difference between data and MC

# Ratios of Branching Fractions

$$\frac{Br(B^0 \rightarrow D_s^+ D^- , D_s \rightarrow \phi\pi)}{Br(B^0 \rightarrow D^- 3\pi)} = 1.95 \pm 0.20(stat) \pm 0.12(syst) \pm 0.49(BR_1)$$

$$\frac{Br(B^0 \rightarrow D_s D^+, D_s \rightarrow K^* K)}{Br(B^0 \rightarrow D^- 3\pi)} = 1.83 \pm 0.22(stat) \pm 0.11(syst) \pm 0.46(BR_1) \pm 0.17(BR_2)$$

$$\frac{Br(B^0 \rightarrow D_s D^+, D_s \rightarrow \pi\pi\pi)}{Br(B^0 \rightarrow D^- 3\pi)} = 2.46 \pm 0.34(stat) \pm 0.17(syst) \pm 0.62(BR_1) \pm 0.34(BR_3)$$

## Branching Uncertainty Summary

- $BR_1$  is due to  $Br(D_s \rightarrow \phi\pi)$
- $BR_2$  is due to  $\frac{Br(D_s \rightarrow K^* K)}{Br(D_s \rightarrow \phi\pi)}$
- $BR_3$  is due to  $\frac{Br(D_s \rightarrow \pi\pi\pi)}{Br(D_s \rightarrow \phi\pi)}$

# Combined Number

CDF Result:

$$\frac{Br(B^0 \rightarrow D_s^+ D^-)}{Br(B^0 \rightarrow D^- 3\pi)} = 2.00 \pm 0.16(NC) \pm 0.12(syst) \pm 0.5(BR_1)$$

Where “NC” - is a combined Non-Correlated uncertainty. It contains

- Statistical error
- Systematics due to  $D_s$  composition in  $B^0 \rightarrow D_s^+ D^-$ ,  $D_s \rightarrow 3\pi$
- $BR_2$  and  $BR_3$  branching uncertainties due to the ratios of branching fractions.

$Br(D_s \rightarrow \phi\pi)$  error is dominating for now, will be reduced by BaBar and Cleo-C.

PDG Result:

- $Br(B^0 \rightarrow D_s^+ D^-) = (8.0 \pm 3.0) \times 10^{-3}$
- $Br(B^0 \rightarrow D^- 3\pi) = (8.0 \pm 2.5) \times 10^{-3}$

$$\frac{Br(B^0 \rightarrow D_s^+ D^-)}{Br(B^0 \rightarrow D^- 3\pi)} = 1.0 \pm 0.4$$